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Introduction to the papers of TWG6: Applications and modelling

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Introduction

The thematic working group 6 (TWG6) in CERME focuses on the research field of teaching and learning mathematical modelling and applications at various educational levels ranging from primary to tertiary education, including vocational courses. The working group also addresses initial and continuing teacher education, where an increasing number of contributions have been offered. TWG6 started at the fourth ERME Congress (CERME 4) in 2005 and it has, since then, continued to be an active thematic working group in the eight meetings through to CERME 11. In total the working group has produced and presented 161 papers and posters.

In its discussions at CERME 11, the thematic working group TWG6 on applications and modelling aimed to seek answers to some open questions in the research field (Schukajlow, Kaiser, & Stillman, 2018), and continue to advance the work from previous ERME conferences. The contributions discussed at the congress are characterized by a strong and fruitful diversity in the research questions considered, the school levels addressed and the theoretical approaches taken. On the whole, TWG6 received 41 papers and posters from 17 countries—most of them from Europe, but also from South and Central America, Iran, South Africa, South Korea and Japan. Finally, a total of 21 papers and 7 posters were presented in the conference, with a total of 40 participants from 14 countries. The next table summarizes the evolution of papers and poster presented in TWG6 in the different CERMEs.

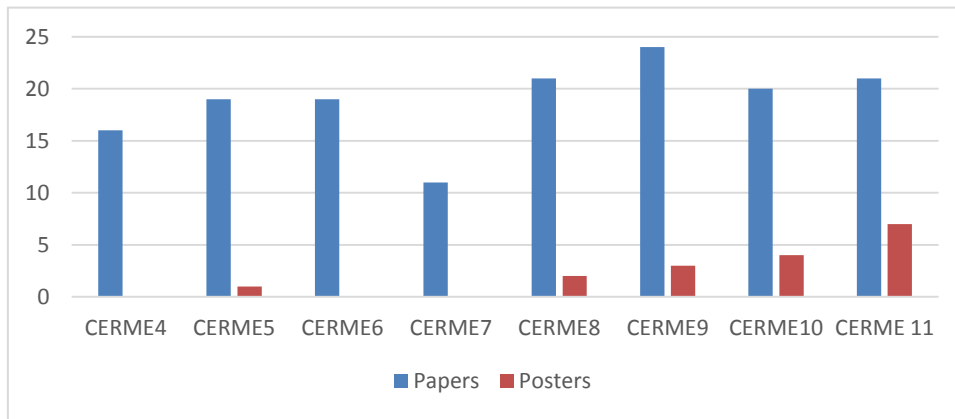


Table 1: Evolution of the papers and posters presented in TWG6

In the seven TWG sessions the different papers were discussed organized around five leading themes, which were established after reading and revision of the submitted proposals. Although some of the papers cover more than one of the identified leading themes, the proximity to other research papers facilitated their distribution among the various themes (Table 1).

<i>Leading themes</i>	<i>Papers</i>
T1. Analysis of modelling processes when solving modelling problems	3
T2. Mathematical modelling and simulations in connection to other disciplines	3
T3. Strategies to support design and implementation of modelling	4
T4. Use of resources to support teaching and learning of modelling	2
T5. Teacher education for modelling and its application	9

Table 2: Leading themes defined and papers assigned in each

As a first important leading theme papers focusing on creating and testing tools for the analysis of the modelling processes that are carried out when students solve modelling problems were identified. These research papers aimed to elaborate specific tools and methodologies for analysing and evaluating modelling practices. The second theme focused on the interplay and connections between mathematical modelling and other subjects, especially in engineering teaching. The third theme addressed different strategies to support the teaching and learning of mathematical modelling; this includes strategies to foster students work on modelling problems, ways in which teachers can guide their implementation and evaluation as well as ideas regarding the design of modelling activities by researchers (and/or teachers). The fourth theme focused on the use of experimental materials and technology in modelling, and covered two topics: the first primarily focused on the role of the auxiliary material and its impact on the modelling activity and a second concerned with how to combine different resources with technology in concept development by means of real word contexts. Finally, the fifth theme covered teacher education for modelling and its applications. As this theme had a lot of contributions, we organized the contributions into two sub-topics. The first topic was about assessing and measuring teaching competencies for mathematical modelling. The second focused on several instructional proposals for prospective and in-service teacher education for modelling and applications.

Leading themes and overarching questions

Analysis of modelling processes when solving modelling problems

This first theme focused on proposing tools and methodologies to analyse the modelling processes individuals or groups of individuals engage in when solving modelling problems. Firstly, *Ärlebäck* and *Albarracín* investigated the potential of extended Model Activity Diagrams as an analytical tool for analysing students' modelling processes by including a sub-division of the modelling tasks at hand in terms of the sub-problems that students work on. Secondly, the paper of *Montejo* and *Fernandez* considered the conceptualisation of the notion of model/s. Based on their analysis of a diversity of definitions about what a model is, according to the educational research literature, the authors introduce a conceptualisation of the notion of model/s as a triplet system-mathematization-representation, and propose for this to be used in future research. Lastly, *Moutet* uses the theoretical framework of the Mathematical Working Space (MWS) to extend the notion of the modelling cycle and to analyse the tasks associated with certain stages of a modelling task in physics, in particular concerning special relativity. This research intends to show how the extended MWS offers a tool for the analysis of the mobilization of the epistemological planes of physics and mathematics and how it relates to the cognitive plane. Although the discussions of the three papers partly focused on different aspects, the following common and overarching questions surfaced in the discussion of the contributions in this first theme:

- What do these new frameworks (or development of existing ones) add to our understanding of, and our research practices in, the field of teaching and learning of modelling?
- What are the implications of these frameworks when considering supporting different communities with modelling: students, teachers or modelling task designers, etc.?
- In what ways can we broaden 'our' perception of what modelling is by comparing different approaches and their interpretation of what modelling is?

Mathematical modelling and simulations in connection to other disciplines

This theme focuses on the role of modelling and simulations when mathematics is integrated with other disciplines. Some of the papers in this theme touch upon parts of the topic of TWG26 - Mathematics in the Context of STEM Education. However, the aim of the papers in this leading theme is to study the role of mathematical modelling in the context of mathematics education rather than the notion of STEM more generally. Within this thematic strand, we find a diversity of studies, proposals and results that easily connect with other leading themes. The paper by *Poudel*, *Vos* and *Shults* describes an empirical study with students of Development Studies, which aims at introducing examples of real research and methods in social sciences to the students. The authors describe their experience from a university seminar on introducing a research approach to the social sciences with the aim of investigating how students use and gain knowledge about modelling and simulations. *Lantau* and *Bracke* present a study about the use of a STEM-modelling project involving the functional principles of a Segway, within a teacher development programme which later guided their implementation of the STEM-project in secondary school settings (grades 10 to 12). Their aims are to analyse the effective factors and obstacles that teachers manifest concerning the implementation of these modelling activities. In the context of STEM-projects, *Ruzika* and

Schneider advocate a multicriteria perspective in relation to mathematical modelling, optimization and decision-making. Their paper presents several examples from real-world problems (including some STEM projects) illustrating the need of multicriteria decision-making and gives some first hints toward incorporating this multicriteria perspective in the teaching paradigm of mathematical modelling. In the general discussion about this theme, we addressed questions such as:

- How can we facilitate and progress the implementing of interdisciplinary modelling projects given regular school conditions (and not only in the modelling-projects weeks, days, etc.)?
- What limitations emerge when adapting modelling projects to school and university conditions? What can be done to favour interdisciplinarity modelling projects in schools?
- What role could or should the other disciplines (natural sciences, social sciences, engineering, etc.) play in mathematical modelling and in mathematical modelling lessons?
- What new disciplinary and interdisciplinary knowledge needs to be introduced and how do we do this in secondary schools and universities?
- Can mathematical modelling be considered as a support for the construction and development of inter-disciplinary knowledge? Which constraints do we have to overcome?

Strategies to support students and teachers in the design and implementation of modelling

The papers related to this topic refer to different strategies to support students when solving modelling problems, teachers when guiding their implementation and evaluation as well as researchers (and/or teachers) with the design of modelling activities. The pursued aims are varied, but when organising their complementarities we found some common questions these papers deal with:

- What strategies do we have (for example: reading strategies and text representations, students' evaluation of given modelling solutions) to help students in modelling? What complementary information can several approaches give us?
- How can the configuration of modelling activities, or their reconfiguration into different modelling problems, serve different teaching and learning objectives? Which principles for the design of modelling tasks may be established?

Related to the first questions, *Dröse* presents research about the impact of fostering reading and comprehension strategies to support students in successfully solving modelling problems. Through the analysis of some particular case studies with students solving modelling tasks, this research focuses on analysing how certain reading strategies can contribute to different steps in constructing mental text representations, which is an important step in modelling. In their work, *Kuntze* and *Eppler* propose that an effective strategy to support students' modelling practices is to ask students to evaluate some particular given solutions of modelling tasks. In particular, this paper presents some empirical findings relating to secondary students when they review and refine modelling solutions cooperatively in the classroom; the students have to face specific requirements, such as reconstructing modelling thoughts, examining alternative modelling steps and comparing the quality of different modelling solutions.

Concerning the second questions, we discussed two papers dealing with task design issues. *Almeida* and *Carreira* present a theory-based discussion on the configuration of modelling activities to show

how the design of modelling tasks is strongly dependent on the perspective adopted for its implementation. Based on some particular examples, an analysis of the task configuration is carried out in light of the more implicit or explicit aims of mathematical modelling in teaching and their connection with various modelling perspectives. From the examples, it is possible to argue that the configuration of modelling tasks is adaptable, which entails flexibility and reinforces the relevance of an educational standpoint in designing modelling problems. Last but not least, *Pla-Castells* and *Ferrando* describe an empirical study with the objective of designing a sequence of modelling tasks focusing on solving a big number estimation problem. They use the so-called downscaling - upscaling techniques for the design of this particular Fermi problem, which is later used to analyse the implementation with primary school students of second grade (7-8 years old).

Use of resources to support teaching and learning of modelling

This theme focused on the use of different kinds of resources: digital technology, physical resources, etc., at the different stages of the modelling process. In particular, some papers aim to discuss the role of the physical or digital prototypes and of simulations at the different stages of the modelling process. In *Baioa* and *Carreira*, the authors explore and discuss the use of simulations with physical models and prototype constructions in the process of modelling. They choose some examples in the inter-disciplinary context of STEM to analyse the use of prototypes and simulations in students' activity going through the entire mathematical modelling cycle. The paper links to *Lantau* and *Bracke*'s research in their detailed analysis of the potential of combining STEM and mathematical modelling. *Lieban* and *Lavicza* discuss the affordances of using and combining physical and digital resources for exploring geometrical modelling. Within the context of pre-service teacher education, the authors explore the use of physical simulation and digital resources, in particular using Geogebra, to support modelling in the transition between 2D and 3D models construction. These papers also establish connections with the aforementioned paper by *Moutet* on the use of digital technologies to simulate physical phenomena involving special relativity. Some of the matters largely discussed were:

- How can we conceptualise simulations within mathematical modelling processes? What do simulations change for model building in the different steps of the modelling cycle?
- How can digital and physical tools change ways of approaching modelling problems? How do they change the meaning of “working mathematically” today?
- Do we need to rethink the definition and conceptualizations of the steps of the modelling processes when using technology and simulations?

Teacher education for modelling and its application

This last theme is the one that attracted most papers. The topic of teacher education is a valued one within the group, based on the acknowledged need of preparing pre-service and in-service teachers for the teaching of applications and modelling. Papers in this leading theme were organised in two sub-topics to facilitate their discussion. The first topic focussed on assessing and measuring teaching competencies for mathematical modelling. The second topic covered works on the proposal of different teacher education courses for pre-service and in-service teachers of primary and secondary school education.

Concerning the first topic, *Borromeo-Ferri* focuses on the question about how mathematical modelling competencies can be assessed and, more concretely, how to see an increase of teaching competencies after a course on ‘learning and teaching of mathematical modelling’. A test instrument was presented and used to assess modelling competencies for students and teachers participating in several empirical studies at secondary level. In their paper, *Klock* and *Siller* emphasize the importance of providing teachers appropriate ways of supporting students working on modelling processes, in particular, through a precise diagnosis in the intervention process. Based on a process model, another instrument for measuring teaching competencies was presented. Thus, based on the data measured by this instrument, the cause-and-effect relationship between a correct diagnosis and the selection of an adaptive intervention can be analysed. Some of the questions that emerged from the group discussion were:

- How to ensure that the test instruments for assessing modelling competencies are significant enough, in the sense of sufficiently independent, from the modelling perspective adopted?
- How can these instruments (assessment, diagnosis, intervention) be useful for teachers’ practice when implementing modelling activities with students?

Closely related to the previous papers, using the conceptualization of the modelling cycle and competencies, and presenting particular instructional proposals we considered several papers. *Wess* and *Greefrath* focus on the modelling-specific task competency of prospective teachers in the teaching laboratory MiRA+. In this laboratory, teachers are encouraged to design their modelling tasks and apply them in practice with emphasis on the acquisition of competency by their students. *Guerrero-Ortiz* present the results developed with prospective mathematics teachers who took part in a seminar with the aim of developing their mathematical and pedagogical content knowledge in the process of designing modelling tasks and discussing about these teaching proposals. Furthermore, *Alwast* and *Vorhölter* discuss the important gap between the theory conveyed at university and the teachers’ practical work at school and how to help future teachers make their knowledge applicable to practice. They use staged video vignettes to simulate real classroom situations and support future teachers episodic memory through repeated practice with these videos.

In their paper, *Yvain-Prébiski* and *Chesnais* identify horizontal mathematization as a crucial component of mathematical modelling. Based on this conceptualization of horizontal modelling, the authors analyse the implementation of a modelling task about the growth of an exotic tree with a large group of secondary school classrooms to analyse how teachers spontaneously manage these initial steps for modelling, especially analysing their difficulties on implementing horizontal mathematization. *Kaneko*, *Saeki* and *Kawakami* aims at creating contact points between empirical modelling and theoretical modelling in teacher education. The authors explore the case of a pendulum modelling problem and the analysis of modelling lessons related to this problem to make teachers reflect on the significance and complementarities between theoretical and empirical modelling.

In her paper, *Jessen* presents a model for upper secondary in-service teacher courses based on the anthropological theory of the didactics and explores how to train teachers to design and implement

mathematical modelling in their classrooms. The course evolves around the proposal of study and research path based teaching and strives to create paradigmatic infrastructures as a framework for collaborative development of teachers' teaching practice. Under the same theoretical approach, *Barquero*, *Bosch* and *Wozniak* address the problem of the teachers' lack of discursive tools to teach modelling processes and how it can be addressed through teacher education. This paper describes a teacher education course with pre-service primary school teachers where the terminology of modelling and the questions-answers maps are proposed to provide future teachers with a discourse—a logos—to explain and analyse the modelling praxis.

Due to the diversity of research questions and of proposals about teacher education, the discussion was particularly rich. Some of the overarching questions addressed when discussing the papers, were the following:

- How does the process of designing modelling tasks contribute to improved knowledge about modelling and modelling processes for teachers?
- How do the course 'elements' impact on the practice of the teachers? What tools are better transferred and adopted by teachers?
- How can we get information (and/or measurements) about the success of teacher appropriation or adoption of the tools introduced in the instruction?
- What different formats, of training teachers for modelling, may lead to a stronger integration of modelling in school contexts?
- Why are we not achieving autonomy amongst in-service teachers with respect to implementing mathematical modelling activities in their classrooms?
- How can we ensure a long-term collaboration between teacher and researchers in the implementation and analysis of modelling activities in regular school conditions?

Concluding remarks and perspectives

The leading themes addressed by the TWG6 show the variety of research approaches and questions the papers dealt with (Kaiser & Sriraman, 2006). Furthermore, the educational levels spanned from primary to tertiary education, also covering teacher education and in-service courses. Comparing the papers and approaches considered to the different perspectives described in Carreira, Barquero, Kaiser and Cooper (2019), that summarises the evolution of the group we can conclude that in CERME 11 the research presented covered most of these perspectives.

In the first theme we discussed the use and applicability of specific tools and methodologies for the analysis of students' modelling processes and its evaluation. The modelling cycle (and its variations) has been prominent in the group. But other approaches to modelling were also discussed, such as Model Activity Diagrams, Mathematical Working Space or the one proposed by the anthropological theory of the didactics. The discussions broadened our focus and opened new questions about possible complementarities between different approaches. Furthermore, a question for future research was about how to transform all the analytic tools for analysing students' cognitive processes into tools facilitating the teacher's task of analysing students' modelling processes.

The second theme focused on the role of modelling in connection to other disciplines. More concretely, on the interdisciplinary approach to the teaching of mathematical modelling, in particular in the context of engineering and STEM education. There is a long tradition in TWG6 of discussing examples under this theme, and we hope to continue to attract work that involves consideration of modelling in different interdisciplinary contexts and practitioners enlightening mathematical modelling from perspectives of other disciplines or contexts.

The third theme, more associated with the instructional perspective, argued for different strategies to support the teaching and learning of modelling, in particular, different approaches to support students in solving modelling problems, and teachers in guiding their implementation and in evaluating modelling activities. Related to this, the fourth theme we addressed focused on the use of technology and physical or digital resources in the teaching and learning of modelling. Questions about “how to conceptualise simulations within the modelling process” or “what do we mean by ‘working mathematically’ when using technology and simulation” have been largely discussed. Moreover, open issues for future research arose from the discussion in TWG6 as, for instance, the need for extending research on teacher education for the use of simulations and modelling.

At CERME 11, teachers and their role in teaching modelling as well as teacher education played a prominent role, as more than half of the papers were dealing with prospective and/or in-service teachers. This shift shows a clear further development of the discussions and the work of TWG6, which needs to be fostered and broadened. Teachers and their professional development are crucial for the integration of mathematical modelling into mathematics education at various levels. Some questions remain open for future research about how to evaluate the impact of teacher training on the use of modelling in the classrooms as well as the teachers’ autonomy in doing so.

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References

- Carreira, S., Barquero, B., Kaiser, G., & Cooper, J. (2019). Introducing CERME’s Thematic Working Group 6 – Applications and Modelling. *Newsletter of the European Mathematical Society, Mathematics Education, ERME Column*, 111, 48-49.
- Kaiser, G., & Sriraman, B. (2006). A global survey of international perspectives on modeling in mathematics education. *ZDM Mathematics Education*, 38(3), 302–310.
- Schukajlow, S., Kaiser, G., & Stillman, G. (2018). Empirical research on teaching and learning of mathematical modelling: a survey on the current state-of-the-art. *ZDM Mathematics Education*, 50(1-2), 5–18.